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Accuracy and safety of pedicle screw fixation in thoracic spine trauma

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Object. The authors evaluated the accuracy of placement and safety of pedicle screws in the treatment of unstable thoracic spine fractures.

Methods. Patients with unstable fractures between T-1 and T-10, which had been treated with pedicle screw (PS) placement by one of five spine surgeons at a referral center were included in a prospective cohort study. Postoperative computed tomography scans were obtained using 3-mm axial cuts with sagittal reconstructions. Three independent reviewers (C.B., V.S., and D.G.) assessed PS position using a validated grading scale. Comparison of failure rates among cases grouped by selected baseline variables were performed using Pearson chi-square tests. Independent peri- and postoperative surveillance for local and general complications was performed to assess safety.

Twenty-three patients with unstable thoracic fractures treated with 201 thoracic PSs were analyzed. Only PSs located between T-1 and T-12 were studied, with the majority of screws placed between T-5 and T-10. Of the 201 thoracic PSs, 133 (66.2%) were fully contained within the pedicle wall. The remaining 68 screws (33.8%) violated the pedicle wall. Of these, 36 (52.9%) were lateral, 27 (39.7%) were medial, and five (7.4%) were anterior perforations. No superior, inferior, anteromedial, or anterolateral perforations were found. When local anatomy and the clinical safety of screws were considered, 98.5% (198 of 201) of the screws were probably in an acceptable position. No baseline variables influenced the incidence of perforations. There were no adverse neurological, vascular, or visceral injuries detected intraoperatively or postoperatively.

Conclusions. In the vast majority of cases, PSs can be placed in an acceptable and safe position by fellowship-trained spine surgeons when treating unstable thoracic spine fractures. However, an unacceptable screw position can occur.

Key Words • trauma • pedicle screw fixation • thoracic spine

Unstable thoracic spine fractures are commonly treated injuries in tertiary-level trauma centers. They are high-energy injuries that are often associated with multiple traumas and spinal cord injury and thus pose challenging patient care issues. Because of the level of the fracture and frequently associated pathological conditions of the chest wall, sternum, and lungs, treatment with an orthosis or prolonged recumbency is often undesirable, making surgery the preferred treatment. Early surgical restoration of alignment and stabilization reduces morbidity[30] and theoretically decreases pain and facilitates reactivation, thus decreasing the length of hospital stay and of rehabilitation.

For surgery in the thoracic region, spine surgeons have usually relied on wires and hooks to stabilize and obtain fixation of the vertebral column. Pedicle screws have traditionally been used more frequently in the thoracolumbar and lumbar spine.[20,21,23,25] Pedicle screws offer considerable advantages over other conventional forms of spinal fixation because they are very effective in reducing spinal deformities associated with trauma without directly encroaching on the spinal canal.[20]

Use of PSs, however, is not without problems. Authors of previous reports have documented a significant rate of misplaced screws, which presents the risk of damage to adjacent neurological, vascular, and visceral structures.[5–13,16,19,32,36,40] In the thoracic spine, PS insertion is difficult because of the smaller pedicle size and the wide variation in morphological characteristics between levels and individuals.[10,11,18,26,27,33,34] Despite these technical and anatomi-

Abbreviations used in this paper: CT = computed tomography; PS = pedicle screw; PSF = PS fixation.

cal limitations, the advantages of PSs have led to their more frequent use in the thoracic spine for elective correction of deformities[1,4,17,24] and to a lesser degree in treatment of injuries resulting from trauma.

The use of PSs in thoracic trauma cases is distinct from their use in elective correction of deformities because surgery after thoracic trauma is often performed outside scheduled hours, when the usual surgical team is not available, and because segmental instability secondary to severe trauma may preclude the accurate use of image-guided techniques. Literature on the use of PSs in the treatment of injuries resulting from trauma has consisted entirely of retrospective reports, except for two studies. In a study of a patient population selected by using restrictive inclusion criteria, Yue, et al.,[39] demonstrated that thoracic PSF is safe and effective in the treatment of a mix of stable and unstable thoracic spine injuries. These authors did not, however, assess the accuracy of screw placement. In the other prospective study, Kuntz, et al.,[22] assessed the accuracy of thoracic PS placement, but their study included a mixed cohort of patients with various diagnoses and pathological conditions that were not limited to the thoracic spine.

Safety is a term that is ill defined when applied to PSF, which probably has a low incidence of catastrophic events. Accuracy may be used as a surrogate for safety. Given the theoretically increased risk of screw malposition in thoracic trauma cases, it is relevant to determine the accuracy and safety of this fixation technique, especially in a population consisting only of patients with unstable thoracic spine fractures. In this study, we investigated the accuracy and safety of using PSs in the open reduction and internal fixation of unstable thoracic spine fractures.

Clinical Material and Methods

Study Protocol

This study was a prospective evaluation of a cohort of patients with unstable thoracic spine fractures treated with PSF. Instability, a controversial concept, was determined using a clinical and imaging evaluation along with the principles of the classification system developed by Denis.[7] Although flexion distraction and fracture dislocation instability are straightforward concepts, burst fracture stability remains controversial. We used the integrity of the posterior ligamentous complex in determining the stability of burst fractures.

The surgeries were performed by five fellowship-trained spine surgeons at the Vancouver General Hospital, a tertiary care center that serves a population of 4 million. The surgeons' clinical practice experience ranged from 4 to 20 years, and each surgeon had placed more than 300 thoracic PSs.

Patients were included if they were between the ages of 16 and 70 years, were admitted to the hospital with an acute (sustained $<$ 2 weeks ago) unstable T1–10 spinal cord injury with or without neurological deficit, and, based on a preoperative CT scan, had a pedicle anatomy that could accommodate surgical stabilization with PS instrumentation. Patients were excluded if they required PSs caudal to T-12 or cephalad to T-1, required anterior decompression, or had pathological conditions of the spine that were not traumatic or were late posttraumatic.

The ethics committees at the University of British Columbia and the Vancouver General Hospital approved this study. Before surgery each patient underwent a standardized clinical and imaging evaluation that included a detailed history and physical examination by the attending surgeon and a review of plain radiographs and CT scans. Magnetic resonance imaging studies were performed to evaluate neurological deficits or suspected posterior ligament injury. Independent study coordinators collected baseline data and demographic information after the patients signed informed consent forms and enrolled in the study. Before discharge, each patient underwent postoperative thoracic CT scanning to assess the PS position. In addition, daily postoperative clinical evaluations were performed to identify systemic or local complications, including neurological, vascular, or visceral injuries that may have resulted from the initial injury or surgery.

Treatment Protocol

Surgical indications were based on individual patient factors, neurological status, and mechanical stability of the injury. The Denis classification[7] was used to categorize fractures and help guide treatment. Preoperative CT scans and plain radiographs were used at the surgeon's discretion to determine the PS starting point and pedicle diameter, length, and inclination in both sagittal and axial planes.

In the operating room patients were positioned prone on a radiolucent Jackson spinal surgery table (Orthopedic Systems, Inc., Union City, CA). Spinal precautions were used while positioning the patients. Spinal cord monitoring is not standard practice for spine trauma surgery at our institution and was not used in these cases. Intraoperatively, standard anatomical landmarks were identified for screw placement,[15] but placement could vary slightly depending on preoperative imaging. The intersection of two lines marked the entry point for PS placement from T-1 to T-10 (Fig. 1). The first line extended along the superior border of the long axis of the transverse process. The second line extended in a cephalocaudad direction approximately 2 mm medial to the lateral border of the superior facet. For T11–12, the entry point for PS placement was the intersection of the horizontal line bisecting the transverse process and the vertical line described previously. A 3-mm high-speed bur was used to initiate the entry point, after which a pedicle awl was used to enter the pedicle. A straightforward insertion technique was used to guide screw trajectory unless the pedicle shape dictated a more anatomically based approach. Two surgeons used fluoroscopic guidance in the operating room, and the other three used the blunt pedicle probing technique (freehand technique) followed by a plain lateral radiography to confirm probe location. Using the freehand technique, the surgeon feels around for a bonelike structure during insertion and uses a thin, ball-tipped probe to assess for violation.

In cases in which lateral projections failed to clearly delineate the bone anatomy, a posterioanterior radiograph was obtained. The Universal Spine System titanium spine instrumentation system (Synthes North America, Paoli,

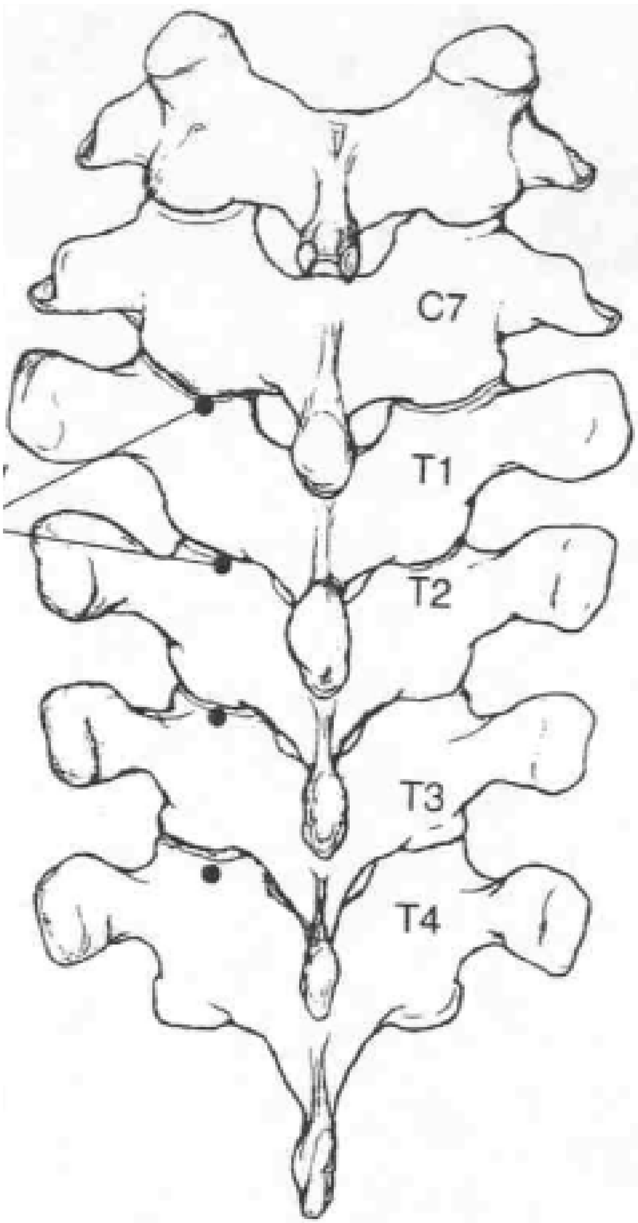

FIG. 1. Schematic drawing of landmarks used for thoracic PS placement.

PA) was used in all patients. Only monoaxial (fixed-angle) screws were used. In all cases anatomical reduction and rigid internal fixation were the surgical goals. Posterior decompression was performed in cases in which it was indicated, but was not done to facilitate PS placement. Local autogenous bone graft was used to facilitate posterior fusion. Postoperatively, early and aggressive mobilization, as tolerated, was the treatment standard. External orthoses were not used.

Imaging Evaluation

Computed tomography scans (CT/i scanner; General Electric Medical Systems, Milwaukee, WI) were obtained in all patients using helically acquired slices with a thickness of 2.5 mm and a pitch of 0.75 to 1.0. The slices were reconstructed at 1.25 mm. The postoperative CT analysis involved an interpretation of PS position by two independent spine surgeons and one independent neuroradiologist who used a radiology diagnostic workstation (IMPAX DS3000 Diagnostic Display Station; Agfa HealthCare, Ridgefield Park, NJ). Pedicle screw accuracy was determined by using a CT grading scale that has undergone both reliability and validity evaluations.[28,29] Interobserver reliability in the present study was moderate ($\kappa = 0.51$), and intraobserver reliability was substantial ($\kappa = 0.63$).

The validity of the CT scan rating scale in assessing the accuracy of thoracic PS placement has been tested by a comparison with direct visualization of the pedicle in cadavers, yielding a kappa statistic of 0.51, which suggests adequate assessment of screw accuracy.[29] In other words, rating of CT scans has been shown to have adequate validity in the determination of true accuracy. When this method is not accurate, it generally overestimates the miss rate.

The PSs in the present study were categorized as situated either completely within the walls of the pedicle or in violation of the pedicle wall. The screws were further subclassified by the location of the perforation (medial, lateral, anteromedial, anterolateral, anterior, superior, and inferior) and by the degree of perforation. The degree of perforation was rated according to the following four categories: Grade 1 (0–2.0 mm), Grade 2 (2.1–4.0 mm), Grade 3 (4.1–6.0 mm), and Grade 4 (6.1–8.0 mm).[1,16,28,29,37,38] Any scans revealing a screw indistinguishable from the cortex were placed in the first category (0–2.0 mm). Any differences in the interpretation of PS positioning among the three observers were discussed, and a consensus decision was made.

Statistical Analysis

The hypothesized observed failure rate of potentially clinically significant PS perforation was approximately 15%.[1,16,24,36] A sample size of 195 was calculated to be required to estimate a true rate of clinically significant

TABLE 1

*Incidence of thoracic pedicle wall perforation among 201 PS placements in 23 patients with thoracic trauma**

	Lt Side (%)		Rt Side (%)		Total (%)	
Level	No. of Screws	No. of Perfs	No. of Screws	No. of Perfs	No. of Screws	No. of Perfs
T-1	1	1 (100)	1	1 (100)	2	2 (100)
T-2	5	1 (20)	5	3 (60)	10	4 (40)
T-3	11	5 (45)	11	4 (36)	22	9 (41)
T-4	9	4 (44)	9	7 (78)	18	11 (61)
T-5	9	3 (33)	10	3 (30)	19	6 (32)
T-6	15	8 (53)	15	5 (33)	30	13 (43)
T-7	14	6 (43)	14	5 (36)	28	11 (39)
T-8	10	1 (10)	10	3 (30)	20	4 (20)
T-9	11	2 (18)	11	3 (27)	22	5 (23)
T-10	6	2 (33)	6	0 (0)	12	2 (17)
T-11	5	0 (0)	5	1 (20)	10	1 (10)
T-12	4	0 (0)	4	0 (0)	8	0 (0)
total	100	33 (33)	101	35 (35)	201	68 (34)

* Perfs = perforations.

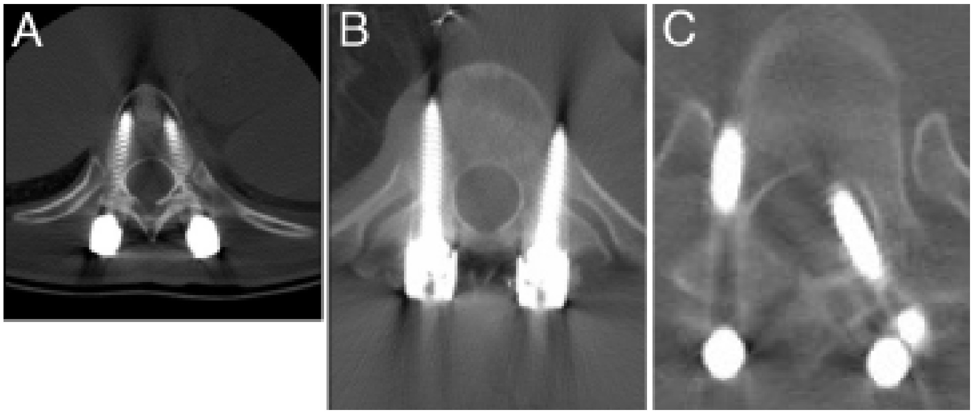

FIG. 2. A: Postoperative CT scan demonstrating placement of PSs fully within the pedicle walls. B: Postoperative CT scan demonstrating placement of PSs with lateral wall perforation. C: Postoperative CT scan demonstrating placement of PSs with medial wall perforation.

pedicle wall violation that would be accurate to within ± 5%, or 19 of 20 instances. A comparison of failure rates between PS placements grouped by selected baseline variables was conducted using Pearson chi-square tests. All probability values were two sided, with a probability value of less than 0.05 indicating statistical significance.

Results

A consecutive series of 23 patients with unstable thoracic spine fractures consented to participate in the study. No eligible patients refused participation. There were 17 male patients and six female patients whose ages ranged from 16 to 53 years, with an average of 33 years. The neurological status of the patients spanned a broad spectrum. Eleven patients were neurologically intact, nine had complete injuries, and three had neurologically incomplete injuries. The fracture patterns were classified by the treating surgeon as fracture dislocation in 12 patients, unstable burst fracture in nine, and flexion–distraction in two.

The total number of PSs placed was 201. In the distribution of PSs between T-1 and T-12, the preponderance of screws were located between T-3 and T-10 (Table 1). Of the 201 thoracic PSs placed, 133 (66.2%) were fully contained within the pedicle wall (Fig. 2A). The remaining 68 (33.8%) were found to be in violation of the pedicle wall. Of these 68 violations, 36 (52.9%) were lateral perforations (Fig. 2B), 27 (39.7%) were medial perforations (Fig. 2C), and five (7.4%) were anterior perforations. No superior, inferior, anterolateral, or anteromedial cortical perforations were found. The position of each screw, the number of screws per level, and the distance and direction of perforation are outlined in Table 2. No adverse neurological, vascular, or visceral injuries were detected intraoperatively or postoperatively.

Lateral wall violations were found for 36 (17.9%) of the 201 PSs. Fourteen (38.8%) of the 36 screws had a Grade 1 violation, 14 (38.8%) had a Grade 2 violation, seven (19.4%) had a Grade 3 violation, and one (2.773%) had a Grade 4 violation. The Grade 4 violation was within 6.5 mm of the lateral border of the vertebral body.

Medial wall violations were found for 27 (13.4%) of the 201 PSs. Sixteen screws (59.2%) had a Grade 1 violation, nine (33.3%) had a Grade 2 violation, one (3.7%) had a Grade 3 violation, and one (3.7%) had a Grade 4 violation.

Anterior wall violations occurred in five (2.5%) of the 201 PSs. Four (80.0%) had a Grade 1 violation, and one (20.0%) had a Grade 2 violation.

With respect to variables that potentially could influence the accuracy or safety of PS placement, Pearson chi-square tests were conducted, but only to determine if potential associations were present. The study was underpowered for any examination of these variables in a definitive way. A comparison between fluoroscopic guidance and standard imaging studies revealed no differences in the incidence of PS cortical perforation. A comparison of failure rates between male and female patients, levels of insertion, regional areas above or below T-6, left- and right-sided insertions, and neurological status groups were performed and revealed no statistical differences.

Discussion

Pedicle screws have become commonplace in the treatment of degenerative and traumatic conditions of the thoracolumbar and lumbar spine.[20,21,23,25] More recently, the biomechanical attributes of PSs and their surgical appeal have led to their use cephalad to the thoracolumbar junction[1,17,20,21] despite risks. The danger posed to various anatomical structures depends on the extent as well as the orientation of pedicle wall violation.[5–13,16,19,32] In a cadaver study, Vaccaro, et al.,[33] described screws placed anterior to the vertebral body cortex as putting the esophagus, azygous vein, and inferior vena cava in danger on the right side. Conversely, the esophagus and aorta are at risk on the left side, and significant lateral wall violation could potentially compromise chest wall integrity.[33]

Our prospective study of 201 thoracic PS placements revealed no neurological, vascular, or visceral injuries, but the study was underpowered to address safety. The results are consistent with the only other published studies in which thoracic PS placement was evaluated.

Yue and associates[39] have prospectively studied placement of 222 thoracic PSs after trauma and observed no adverse events. However, these results could be misleading

TABLE 2

Location and degree of pedicle wall perforation among 201 PS placements in 23 patients with thoracic trauma

		Pedicle Wall Perforations												
			Medial				Lateral				Anterior			
Level	No. of Screws	None	Grade 1 (0–2.0 mm)	Grade 2 (2.1–4.0 mm)	Grade 3 (4.1–6.0 mm)	Grade 4 (6.1–8.0 mm)	Grade 1 (0–2.0 mm)	Grade 2 (2.1–4.0 mm)	Grade 3 (4.1–6.0 mm)	Grade 4 (6.1–8.0 mm)	Grade 1 (0–2.0 mm)	Grade 2 (2.1–4.0 mm)	Grade 3 (4.1–6.0 mm)	Grade 4 (6.1–8.0 mm)
T-1	2	0	0	0	0	0	0	1	1	0	0	0	0	0
T-2	10	6	0	2	0	0	0	0	1	0	1	0	0	0
T-3	22	13	1	2	1	0	0	2	1	1	0	1	0	0
T-4	18	7	2	1	0	1	2	2	2	0	1	0	0	0
T-5	19	13	1	1	0	0	2	1	0	0	1	0	0	0
T-6	30	17	5	0	0	0	4	3	0	0	1	0	0	0
T-7	28	17	4	2	0	0	1	3	1	0	0	0	0	0
T-8	20	16	1	0	0	0	1	2	0	0	0	0	0	0
T-9	22	17	2	0	0	0	3	0	0	0	0	0	0	0
T-10	12	10	0	1	0	0	1	0	0	0	0	0	0	0
T-11	10	9	0	0	0	0	0	0	1	0	0	0	0	0
T-12	8	8	0	0	0	0	0	0	0	0	0	0	0	0
total no. (%)	201 (100)	133 (66.2)	16 (8.0)	9 (4.5)	1 (0.5)	1 (0.5)	14 (7.0)	14 (7.0)	7 (3.5)	1 (0.5)	4 (2.0)	1 (0.5)	0 (0.0)	0 (0.0)

because neither our study nor the study by Yue and associates was sufficiently powered to evaluate safety. Safety spans a wide range of outcomes, the most severe of which is death or paralysis. The incidence of the most severe safety outcomes would dictate the need for a huge cohort. We selected accuracy as a surrogate for safety. Yue and associates addressed the efficacy of thoracic PSs but did not examine the accuracy of placement. Patients with a pedicle diameter of less than 7 mm were excluded from their study and all three surgeons in the study used the same operative technique with fluoroscopy.

Kuntz and colleagues[22] have also addressed the efficacy of PSs in a series of surgeries performed by one surgeon, who used fluoroscopy in every case. The study population, however, consisted of a mixed cohort of patients in terms of etiology and level, with only about one-half of the 209 screws in that study limited to the thoracic spine.

Our study differs from these previous studies in several ways. In our study, pedicle diameter was not an exclusion criterion, as it was in the study by Yue and associates.[39] More than one surgeon performed the surgeries in our study, whereas only one surgeon was involved in the study by Kuntz and colleagues. The surgeons in our study used various intraoperative imaging techniques, whereas a single modality was used in both of the previous studies. Furthermore, the cohort in our study was much more homogeneous than that in the study by Kuntz and colleagues, and the overall fracture severity in our study was greater than that presented in both previous studies. These differences suggest that our study has the characteristics of an effectiveness study, and therefore the results are more generalizable for severe thoracic spine trauma.

In the current study, PS containment was observed in 66.2% (133 screws) of the screw placements, and pedicle wall violation was found in 33.8% (68 screws). These rates compare relatively favorably with results reported in the literature on correction of both coronal- and noncoronal-plane deformities, in which containment was 42% (coronal) to 57 and 62% (noncoronal), when anatomical landmarks and fluoroscopy were used in the surgical technique.[2]

Pedicle wall violations were observed in only the anterior, medial, and lateral directions. It is interesting to note that we found no inferior perforations that would potentially compromise the exiting nerve root. This finding is relatively consistent with the literature.[1,4,38] Grade 1 perforations were found for 16.9% (34 of 201) of the screws, and Grade 2, 3, and 4 perforations were found for another 16.9%.

Our data showed that the anterior perforation was most often due to the sharp tip of the screw, which was far away from the visceral structures. This screw placement was believed to be acceptable for the purposes of grading; however, we recommend using a screw 5 mm shorter than the depth guage–measured length to ensure that perforation of the anterior cortex is avoided. Bicortical purchase is not advocated and should be avoided. In the one case of a Grade 2 anterior violation in our study, the PS was close to the aorta on the postoperative CT scan, and, although no vascular or visceral complications resulted, revision to a shorter PS was required.

The lateral cortex violation was most likely due to an underestimation of the pedicle transverse angle, resulting in the "in-and-out" technique of PS placement recognized in the literature as an extrapedicular PS insertion. Dvorak, et al.,[8] have shown that this insertion is safe, biomechanically stable, and well shielded from the chest cavity by the rib head. The surgeon's bias to avoid the spinal canal with the screw, especially in a setting of small thoracic pedicles, would lead to a higher prevalence of lateral wall violation, which was observed in the study by Kuntz and colleagues.[22] Although no anterolateral violations occurred in our study, it is important to ensure an osseous end point during depth-gauge evaluation and to choose a significantly shorter screw to avoid aortic injury on the left side.

The medial perforations that were greater than 2 mm were likely the result of an overestimation of the transverse pedicle angle. It may be that only medial penetrations greater than 4 mm are of concern, given the theoretical "safety zone" that exists before neurological problems are seen.[16] According to our data, two screws were placed medially beyond the 4-mm safety zone. One was at T-3 and was rated as a Grade 3 (4.1–6.0 mm) violation; the other was at T-4 and was rated as a Grade 4 (6.1–8.0 mm) violation. Both were placed in the same patient, who preoperatively had a complete neurological injury. The treating surgeon recognized this medial wall perforation intraoperatively and, considering the presence of a complete neurological injury and the solid purchase of the screws, elected not to revise the screws. Postoperatively, after reviewing CT scans, the same surgeon decided that the observation was sufficient and that the screws did not require revision. This approach is controversial. The decision to leave the screws in place is based on a risk–benefit analysis in which many factors are considered, and this approach necessitates continued observation. It is important to note that misplacement of screws can occur, even during procedures performed by experienced surgeons. Caution, meticulous technique, and careful clinical and imaging follow-up examinations must be used.

Gertzbein and Robbins[16] first postulated that a medial PS violation of up to 4 mm is an acceptable thoracic position for the screw because it still allows for a safety zone in which there is 2 mm for the epidural space and 2 mm for the cerebrospinal fluid within the subarachnoid space; however, this postulation was based on the results of a T-8 CT myelogram obtained in one patient. On the basis of cadaveric studies, lateral perforations of up to 6.8 mm may also be considered acceptable, because the rib head shields the chest cavity from screw perforation.[8] Considering these parameters, although our study results showed that 133 (66.2%) of 201 screws were fully contained within the pedicle, in fact we ultimately found that 198 screws (98.5%) were acceptably placed; thus, three were unacceptably positioned (two medial perforations and one anterior perforation).

The definition of an acceptable screw position, however, is controversial. The sample size in this study was calculated using an estimated 15% clinically significant failure rate of PS insertion. This rate was based on the literature.[1,16,24,36] Failure of PS insertion is generally defined as a wall violation greater than Grade 1 (> 2 mm). However, clinical consequences may not result until a wall violation greater than Grade 2 (> 4 mm) occurs. The prevalence of this degree of wall penetration is reported to be much lower in surgeries performed for correction of deformities.[1,17] As a result, the current study is underpowered to estimate the true rate of "clinically safe" pedicle wall violation.

Radiographic determination of the location of PSs can be quite difficult. Other authors have reported inaccurate identification of misplaced screws by using plain radiographs.[3,35] Computed tomography scans constitute the most useful modality for determining dimension and PS malposition.[14,31] The CT grading scale used to determine accuracy in this study has been evaluated for reliability and validity.[28,29] Although the reported kappa statistics were respectable, in the validity testing the positive predictive value of CT scans was 95% and the negative predictive value only 62%.[28,29] Thus, grading of CT scans will tend to result in overestimation of misaligned screws, with a bias toward the screw accuracy being better than reported.

The results of the present study revealed no associations between surgical variables and accuracy, but it was not powered to do so. In a few studies investigators have demonstrated that obtaining a preoperative CT scan, performing an open laminotomy, or using intraoperative fluoroscopy all result in similar rates of pedicle violations.[36]

Other than the previously discussed power issues, several limitations of this study should be noted. No analyses were performed to examine PS hardware failure rates, loss of fracture alignment with time, and, most important, the functional outcomes of these patients during long-term assessment. These analyses were not an objective of this study; however, we are prospectively collecting these data. An accurate account of resident and fellow participation in screw placement would have been valuable for improvement of training. All five attending surgeons had extensive experience before the study commenced, and we do not believe that a learning curve was an issue in this study.

To our knowledge this is the first prospective study performed to evaluate the accuracy and safety of PS use in a well-defined cohort of patients with thoracic spine fractures. Our results, as well as those of others,[1,4,17,38] have shown the technique to be relatively accurate in the hands of experienced spine surgeons, for both correction of deformities and treatment of injuries resulting from trauma. Accuracy of placement of thoracic PSs in the trauma population is similar to that in the population with deformities. Although these results must be interpreted cautiously, they are encouraging because they suggest that the anatomical, biomechanical, and practical advantages of PSs can probably be safely applied in the treatment of thoracic trauma, just as they have been in the treatment of pathological lumbar and thoracolumbar conditions. Surgeons using this method, however, must be educated in the technique and must be cognizant of the anatomical issues and potential complications. The need for training and awareness of potential complications is supported by our findings of two misplaced medial screws and one long anterior screw in this series. Technical suggestions from this and other studies should be applied to prevent misplaced screws. Finally, the concept that accuracy may not fully represent safety must be remembered.

Conclusions

The findings of this study demonstrate that PSs can be used in unstable thoracic fractures with a high degree of acceptable accuracy, with the caveat that an unacceptable screw placement can occur, even in surgeries performed by experienced surgeons. There were no complications with screw placement by the experienced surgeons in this study, but the study was underpowered for determining catastrophic complications. Therefore, we cautiously recommend the use of PSs in unstable thoracic spine fractures by appropriately trained surgeons who remain cognizant of the potential pitfalls.

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